Attachment 6.2 –Supporting Documents

Monitoring, Assessment, and Performance Measures

Project B – Ash Slough Arundo Eradication and Sand Removal Project

Madera Region – IRWM Implementation Grant Application

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Arundo Surveying and Monitoring Protocol

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I. Overview

The Arundo Eradication and Coordination Program Surveying and Monitoring Protocol is a complete data collection and management system approved by Team Arundo del Norte for the standardized collection and reporting of three kinds of information: 1) an initial site survey which includes Area descriptions and Area Surveys, and Weed Occurrences and Weed Assessments, 2) Treatment information, and 3) follow-up monitoring accomplished by collecting subsequent Weed Assessments and Area Surveys which capture changes in plant communities through weed eradication and by passive or active revegetation. Timing of the data collection will depend upon several factors, including landowner permission, when the eradication is to take place, and weather and stream conditions. Follow-up monitoring will be conducted at least once per year for three to five years following eradication in order to assess its effectiveness.

Initial surveys and monitoring data collection is done using the Weed Information Management System (WIMS) database application, version 3.0. The WIMS 3.0 application and support materials can be found at http://teamarundo.org/survey/. Support for partners is provided by the Sonoma Ecology Center GIS & Information Services Program, co-developers of the WIMS 3.0 application. The data system design is compliant with the North American Weed Management Association's International Standards for Inventory, Monitoring, and Mapping of Invasive Plants.

II. Data Collection Protocol

Partners are trained in the standard protocol and the use of GPS, maps, and photo documentation to develop the survey and monitoring data necessary to track the success and cost of eradication and monitoring efforts over the time period of the project and beyond. Data gathered is described below. For more information see http://teamarundo.org/survey/

A. Initial Site Assessment and Arundo Observations

An initial site assessment and Arundo observations are collected as part of the partner's Arundo Eradication Plan, which is required before any eradication work is undertaken. The information collected in this initial assessment guides the planning of the project, from landowner contact to choosing the appropriate eradication methods. The assessment may be done rapidly using simple paper forms with drawings on paper maps, or the WIMS application may be used. If a rapid assessment is done, more thorough data will be collected at the time of first treatment. This data will be used as the baseline description of the site so that it can be compared with data obtained during follow-up monitoring. All partners are required to collect baseline, treatment, and follow-up monitoring data, and to report it, as described below.

The data collected in a *rapid assessment* includes:

- Area descriptions with information about owner and other contacts, permission, and instructions for access.
- A weed occurrence description, with species name and a point or polygon on a map.

The data collected for a *complete baseline description* includes:

- Area descriptions with information about owner and other contacts, permission, and instructions for access.
- A survey for each area, noting and describing presence or absence of Arundo and other weeds, other (especially native) plant populations, and disturbances.
- Weed occurrence descriptions, with species name and GPS data (centroid point).
- A Weed Assessment for each Weed Occurrence, with a GPS polygon showing the extent of the population, and data describing the status of the weed such as percent cover, distribution, and phenological stage.
- A session log, recording the crew and staff time required to accomplish the observations.
- Photos of the surveyed areas and weed populations associated with a GPS point and compass direction.

B. Treatment/Revegetation Log

Data collected at the time of treatments includes:

- A Weed Assessment for each Weed Occurrence being treated (see above).
- A Treatment record describing the eradication or revegetation methods used.
- A Session record, recording the crew and staff time required to accomplish the treatments and observations.
- Photos of the treated areas and weed populations associated with a GPS point and compass direction.

C. Follow-Up Monitoring

Monitoring will be done to document and evaluate the success and costs of Arundo control and any revegetation efforts, and allow a comparison of the methods employed. Monitoring information will be collected several times over a period of three to five years. GPS points from the original survey are used to navigate to the treated Arundo stands. The information to be collected is described above under Initial Site Assessment and Arundo Observations, and the data collected will be the same. Repeated observations of site environmental quality and Arundo population status will allow for evaluation of the success of treatment. Photos of the site and treated Arundo will be taken from established photo-points for before and after comparisons.

III. Data Storage and Reporting by Partners

Field data collected by Eradication Partners is to be entered into the Weed Information Management System (WIMS). The weed manager creates and manages the data at his or her personal computer. The data collected by partners is sent to Sonoma Ecology Center on a quarterly basis for combination into a single GIS so it can be viewed and analyzed together for Arundo locations, spread, impact, and eradication method effectiveness. This digital, standardized data can also be readily combined with other important California weed databases such as CalFlora, the California Information Node of the National Biological Information Infrastructure (CAIN), and shared with others such as TNC and California state agencies.

IV. Data Analysis and Sharing

Monitoring using this protocol will enable the analysis of the cost and effectiveness or outcome of the eradication and any revegetation effort employed, the amount of Arundo eradicated, and changes in the plant populations at the invaded site. Individual partners may create reports at any time showing acreage of weeds treated and untreated, staff hours spent on the project, methods used and their results, and costs of the treatments. Data combined for the ten partners will be analyzed together to compare effectiveness of different methods and similar methods used in different locations. Locations of weed populations, the organizations working at those sites, and data describing treatments will be displayed on the dynamic map server on the Team Arundo del Norte website. Analysis results will be shared when they become available using the website. Data will be filtered for publication on the web to protect the privacy of landowners.

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Attachment 6.2, Geoweed One-Page Handout

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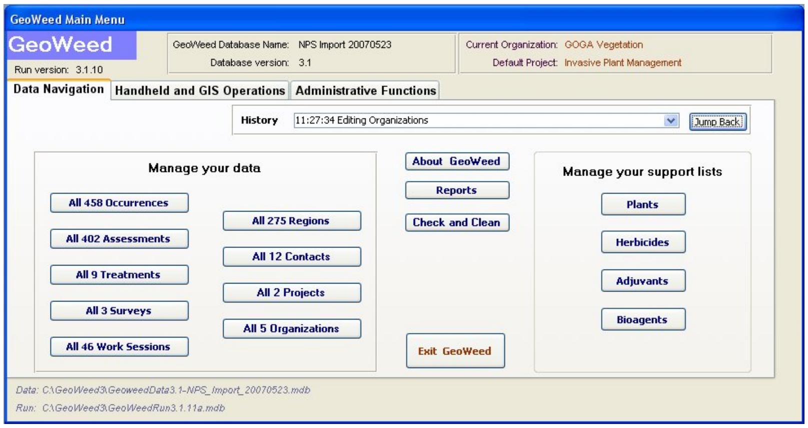
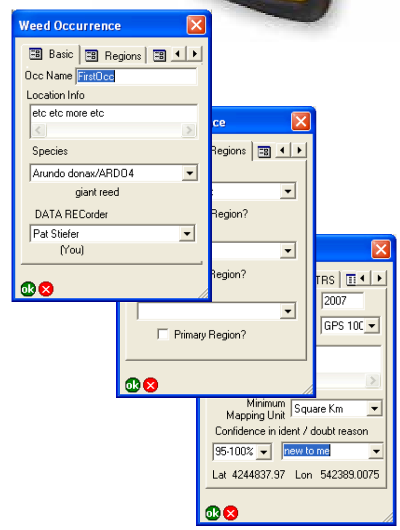
GeoWeed

GeoWeed is a geospatially enabled data system for invasive plant project managers, supporting quality data capture, use, management, and aggregation



A powerful and intuitive user interface provides for rapid access to and review of data.



GeoWeed allows the weed manager to record locations of invasive plants for monitoring and management. Plant population sizes and locations, treatments, and revegetation actions may be tracked over time using GPS or aerial photos. Many types of supporting information may be recorded and managed, including photographs, labor sources and hours, and important contacts. GeoWeed is derived from TNC's WIMS and is based on the same NAWMA superset core data elements of Occurrence, Assessment, and Treatment, with the addition of a Survey.

Software Features:

- Desktop application runs in MicroSoft Access 2003
- Field application runs on handheld PDA using ESRI ArcPad 6 or 7
- Referential integrity and split client/server database for robustness
- Record multi-species surveys including absence data
- Record, review, and manage monitoring photographs
- Error flagging, checking, and correction tools
- Extensive data selection and filtering tools

Training and Support:

- Comprehensive User Guide and training slide shows available on the GeoWeed website
- Contact Sonoma Ecology Center about training workshops and user support

GeoWeed 3.3 has been released- please see the GeoWeed website for software, user guide, slide shows, and future directions. GeoWeed is a project of Sonoma Ecology Center and is distributed as free and open source under the GNU General Public License.

http://geoweed.org

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Attachment 6.2, Geoweed Information

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What is GeoWeed

GeoWeed is a geospatially enabled data collection and management tool for invasive plant project managers.

GeoWeed allows the weed manager and their field crews to record locations of invasive (or any) plants for early detection and management. Plant population sizes and locations may be tracked over time to monitor change using GPS points or polygons. Treatments and labor can optionally be tracked with a choice of granularity level.

GeoWeed uses a superset of the NAWMA weed mapping standard, and contains mostly a superset of the data collected in TNC-WIMS.

GeoWeed is free and open source software.

GeoWeed Features:

- Main application runs on desktop/laptop Windows XP computer using MS Access 2003.
- Satellite application for field use runs on handheld PDA using ESRI ArcPad 6 or 7.
- For any species (can be used for non-invasive plants as well)
- Record locations of patches (point / polygon), from GPS or maps
- Track history (size and status of patch over time, treatments applied)
- Record surveys (multispecies survey including absence data)
- Track photographs
- Records NAWMA superset
- Derived from TNS-WIMS, mostly superset of WIMS data.

GeoWeed is primarily for those involved in efforts to fight invasive plants and weeds.

It can also be used to track non-weed plants, and in particular has been used to record and map locations of protected plants (to aid in permitting).

It can be used for early detection, for ongoing assessment, and for tracking treatments.

Some current or potential users:

- Parks (National, State, Regional, Local)
- Watershed or natural area conservancies
- City, County, or State government agencies
- Weed Management Agencies (WMAs)
- Conservation Districts / Resource Conservation Districts
- Large private landowners
- Researchers
- **Q: How much does it cost?**

- GeoWeed is free, under a Gnu Public Licence (GPL)
- **Q: How can I obtain it?**
- Register on the GeoWeed.org website and download it.
- **Q: What support is available?**
- First, read our User Guide, available on this website.
- Team Arundo del Norte partner can contact the Sonoma Ecology Center for support during the term of their AECP (Arundo Eradication and Control Project) contracts.
- All users may find answers to their questions on the Forums, and can post new questions. Other users and the Sonoma Ecology Center staff will respond as they can. Unfortunately the Sonoma Ecology Center has very little funding for supporting users other than TAdN.
- Other support arrangements (contracts or fee per service) can be arranged. Contact us!
- **Q: Is GeoWeed compatible with NAWMA and other standards?**
- GeoWeed collects a superset of the North American Weed Management Association (NAWMA) Weed Mapping Standard, as well as the related California Weed Mapping Handbook.
- GeoWeed's weed tracking model expands upon the NAWMA model by tracking an identified weed patch over time; a given weed patch may have one Occurrence record with data that is mostly time invariant (such general location, species), along with one or more Assessment records, each being a snapshot of the state of that patch at a given time (including eradication). This can however be reduced to the simpler NAWMA model by combining data from both records to export a simple NAWMA compatible flat file.

History of GeoWeed

GeoWeed is a member of the **WIMS** (Weed Information Management System) family of software. Our rough lineage:

- 1990's: *Bureau of Land Management* in Idaho creates weed database
- 2000-2005: *The Nature Conservancy* enhances it as **WIMS**
- 2006+: *Sonoma Ecology Center* creates **GeoWeed** from WIMS

According to *The Nature Conservancy* (TNC), the lineage began with a weed database that was initially developed by Danielle Bruno, who worked for the Bureau of Land Management's (BLM) Boise-Vale District in Idaho. The Nature Conservancy adopted that codebase in 2000 and developed it as **WIMS**, adding many enhancements. The primary programmer for WIMS was and is Barry Lavine.
In 2006, the *Sonoma Ecology Center* (working with *The Nature Conservancy*) chose WIMS as the initial code base for an expanded functionality database for use with Team Arundo del Norte. The primary programmers have been Barry Lavine, Marat Gubaydullin, and Zhahai Stewart.

The new database was initially called "WIMS 3 beta" and used by less than a dozen close partners. As it evolved away from TNC-WIMS and was beginning to be offered to the wider community, it was agreed that it should have a new name to avoid confusion with TNC WIMS, and the name **GeoWeed** was chosen in 2007. We continue to be a proud member of the WIMS family and to appreciate the contributions of The Nature Conservancy and WIMS.

WIMS continues to be supported and enhanced by The Nature Conservancy. GeoWeed might be considered a "fork" in the software development path, rather than a replacement for WIMS. As with most software development forks, GeoWeed evolved to meet a somewhat different vision or focus, as described below. As a very rough estimate, perhaps somewhat more than half the code in WIMS was modified or replaced, and a good deal more added along with new tables and forms.

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Attachment 6.2, Preliminary Comparison of Transpirational Water Use by *Arundo donax* and Replacement Riparian Vegetation Types in California

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Preliminary Comparison of Transpirational Water Use by *Arundo donax* and Replacement Riparian Vegetation Types in California

Report to Madera Co. RCD, Elissa Brown
From: Tom Dudley, Marine Science Institute, U.C. Santa Barbara
& Shelly Cole, Environmental Sciences Program, U.C. Berkeley

Introduction

Arundo donax or giant reed is hypothesized to cause excessive losses of groundwater to the atmosphere, based on an assumption that it has high transpiration rate during photosynthesis relative to other riparian plant types, and that its large leaf surface area facilitates even greater water consumption and transport (Dudley 2000). Some initial comparisons do suggest that it may transpire almost double the amount of water as does a native willow in northern California under some circumstances (Zimmerman 1999, Hendricks et al. 2006). Researchers in Texas indicate that *Arundo* has high transpiration output but associated plant types were not compared in that case (Watt et al. 2008). In semi-arid riparian areas of California and the Southwest excessive transpiration by invasive plants potentially exerts pressure on natural or managed ecosystems by exhausting surface water and depleting groundwater (Shafroth et al. 2005). Documentation of such effects would provide a solid basis for implementing control programs for invasive plants such as *Arundo* if it can be shown that replacement by native or other plants that transpire less water could enhance water availability for wildlife and human uses.

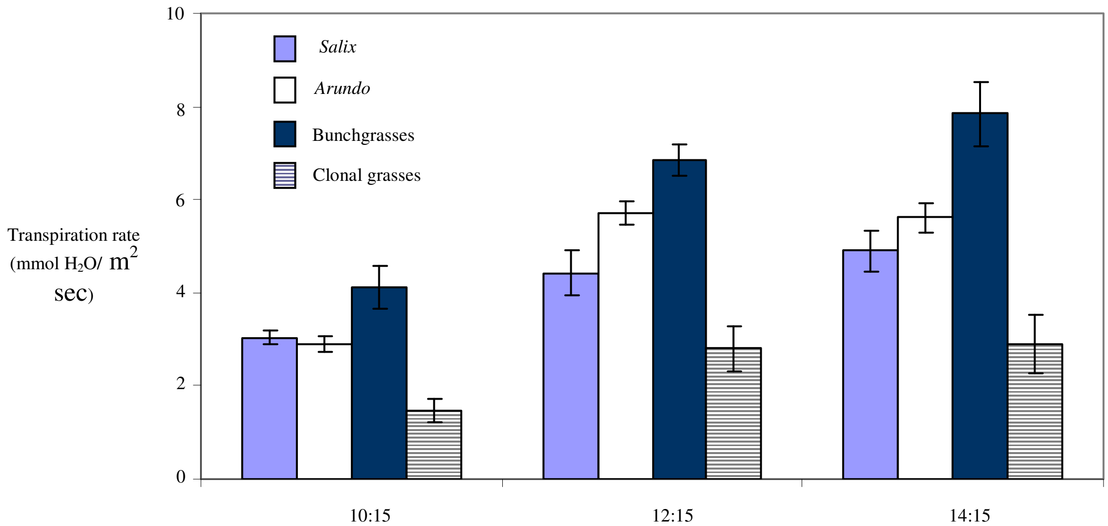
We conducted a comparison of water use by four vegetation types, including *Arundo*, a native willow, large-statured bunch grasses and prostrate, clonal grasses, to determine the relative amount of sub-surface water that are transpired to the atmosphere during the warm season in California. This trial study was conducted at the Hedrick Conservation Area (HCA), a private nature reserve on the Santa Clara River in Ventura County. *Arundo* and red willow (*Salix laevigata*) were plants that we had grown in an experimental 'plantation' for other ecological studies (Coffman 2006); the other plants were either installed in restoration efforts or existed naturally at the HCA within 200 meters of the plantation, and included 'bunch grasses' (*Leymus triticoides* – creeping wildrye*, Elymus condensatus* – giant wildrye) and 'clonal grasses' (*Distichlis spicata, Cynodon dactylon*). Weather data used for calculating moisture dynamics were from the nearby U.C. Coop. Extension Hansen Agricultural Center.

The trials were conducted at the beginning of September and consisted to 4 days for collecting data. Leaf-level moisture flux (transpiration) was measured using Lincoln Corporation portable photosynthesis unit (LiCor 6100) at three times of the day, mid-morning, mid-day and early afternoon, to reflect daily variation in temperature and light intensity. The LiCor test chamber would be used to measure moisture flux from two leaves on each test plant, the leaves chosen to be the uppermost (newest) on a given stem that had fully opened; measurements were replicated on a minimum of five plants for each treatment group (*Arundo*, *Salix*, bunchgrass, clonal grass). Whole plant transpiration was then estimated by extrapolating unit-leaf area moisture flux measurements to whole plant leaf area, which was determined by harvesting sub-portions of the test plants and measuring leaf dimension to calculate whole-plant leaf area.

Results

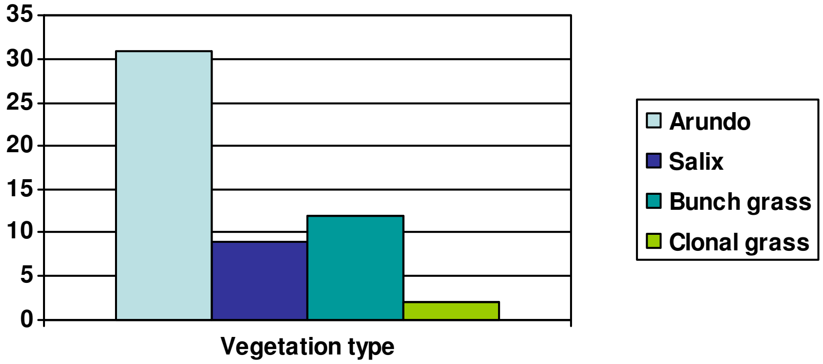
The following table presents values for transpiration (or water loss) through foliage of the experimental plants. These are estimates for a standardized leaf surface area, and indicate that generally willow (*Salix laevigata*) is roughly similar to *Arundo donax* on a leaf-area basis, that our 'bunch grasses' (*Leymus triticoides, Elymus condensatus*) are more water-consumptive, and 'clonal grasses' (*Distichlis spicata, Cynodon dactylon*) use substantially less water when standardized for leaf area. Note, however, that during the high light-intensity mid-day period, *Arundo* transpired approximately 25% more water than did the willow; these differences were statistically significant. This suggests that *Arundo* has an inherent higher capacity to continue transpiration (or photosynthesis) at a high rate when under excessive light conditions, while willows may respond to by reducing photosynthetic rate. Such photo-inhibition is well-documented in many plants, and it is likely that this dichotomy also exists between *Arundo* and willows too. This would translate into substantially larger daily ET rates for *Arundo*, once transpiration values are integrated over the full daylength period.

Transpiration rates for target vegetation types at the Santa Clara River



The more critical comparison, however, is transpiration on a per-unit ground area basis. We calculated the photosynthetic area, or leaf area, for 4 plants of each plant type, as well as the average ground area occupied by that plant (its 'footprint'). The estimated leaf area per m^2 for the four vegetation types at our study site on the Santa Clara River were: willow 1.1 – 2.9 m^2 ; *Arundo* 3.7 – 6.7 m^2 ; Clonal grasses 0.3 – 0.8 m^2; Bunch grasses 1.0 – 2.4 m^2. By using

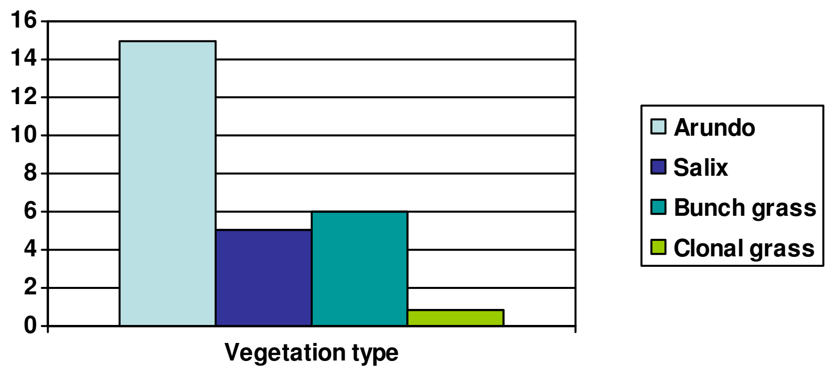
Relative water use by invasive or replacement plant types at the Santa Clara River



the mid-range values for leaf-area, and the mid-day transpiration rates, the relative water use by these 4 vegetation types is: *Salix* – 9 units water (on a relative basis); *Arundo* – 31 units; Bunch grasses – 12 unit; Clonal grasses – 2 units water.

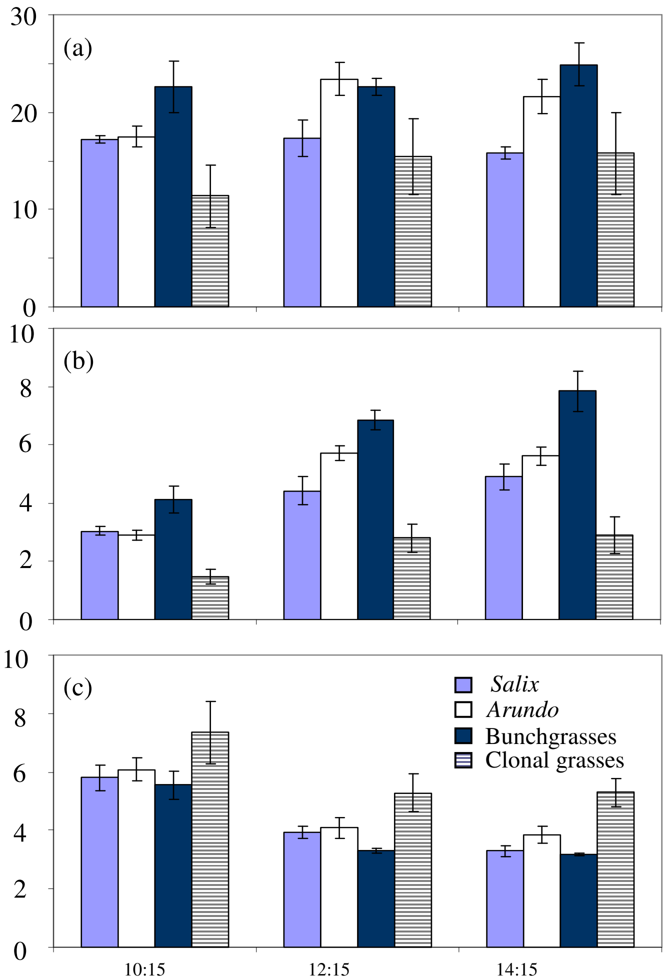
A rough prediction of the actual amount of water transpired to the atmosphere by each vegetation type can subsequently be calculated as the product of the transpiration volume per second over the time period that plants are photosynthetically active, and extrapolating this value to plant leaf area. For the late summer period when measurements were taken, we estimated the period of active photosynthesis as being 10 hours long (discounting morning and evening hours when light incidence is relatively low), and extrapolated interim hourly values between the three measurement points as a curvilinear relationship. This yielded a range of daily water use values from 0.015 m^3 (15 l.) per m^2 ground area with *Arundo* to 0.0008 m^3 (0.8 l.) for *Cynodon* and *Distichlis* clonal grass forms. That would be equivalent to 150 m^3 of water loss per hectare of *Arundo*-infested riparian area per warm, sunny day, or approximately 0.12 acre-feet per day.

Estimate daily mid-summer water use by target plant types (liters per day per m^2)



These values could be further extrapolated to annual water use quantities by estimating the transpiration rates per unit time at different times of the year, but for several reasons this is beyond the scope of the preliminary data we have generated. For purposes of discussion, we might assume that these mid-summer transpiration values are representative of 4 warm months, that 4 spring and fall months produce half as much water use, and during winter there are 4 months of transpiration rates about 15% of summer rates. Based on these conjectures, *Arundo* may remove approx. 3.0 m^3 of groundwater to the atmosphere for every m^2 of infested land area, compared with 1.0 to 1.2 m^3 for native vegetation; 0.16 for groundcover 'clonal' grasses; this would be equivalent to drawing down the groundwater level by the same numerical relationship (e.g. 3 m by *Arundo*) if the whole system was comprised of that vegetation type. We cannot stand by these estimates, however, because transpiration is highly dependent upon air temperature and relative humidity, on water availability, and on the amount of total leaf area and shading that would exist at different times of the year. Although *Arundo* is presumed to be more metabolically active during winter months than are willows and so would certainly be relatively even more water-consumptive at that time of year, we are unable to make a rational evaluation of actual seasonal water use because of the lack of appropriate data needed to make such calculations.

The following graphs of PS rates and Water Use Efficiency expand the relationships described previously (the above Transpiration graph is ‘b’), although they are more complex than is easily explained in this preliminary report. WUE suggests that the clonal grasses are most efficient at photosynthesis with respect to water used, while *Arundo* is marginally more efficient than the willows it has displaced.



The (a) photosynthetic rate (µmol/m^2 sec), (b) transpiration rate (mmol/m^2 sec) and (c) water use efficiency (mmol CO_2/molH_2O) of study plants at three time periods. *n*=5 and bars indicate ±1 SE.

Discussion/Preliminary Conclusions

It appears that under warm-season conditions in semi-arid regions *Arundo* uses roughly three times as much water as do moderate sized replacement species (red willow, ryegrasses) that also provide some habitat value for wildlife, and about 15 times more water than does a low-quality grass such as native saltgrass or introduced bermudagrass. This may translate to roughly 0.12 acre-feet of water use by an acre of *Arundo*-infested landscape, one-third that among by willows (0.04 ac-ft) and large grasses (0.05 ac-ft), and somewhat less that 0.01 acre-feet by low-growing native or exotic grasses.

One caveat is that there are certainly areas where *Salix* and other plants have a greater (or less) leaf surface area than we found at this site, so our results are not robust across a larger region without correction for the leaf area present per meter-square of land surface. We did, however, find roughly similar results when the same approach was taken in comparing *Arundo* and *Salix exigua* in northern California (Zimmerman 1999). In that study, transpiration per unit leaf area was more equivalent between the two taxa, but the leaf area of *Arundo* was approximately double that of *Salix* so the water losses through *Arundo* were consequently about double that lost through willow photosynthesis.

It is important to note that these are very preliminary results, and firmer conclusions must wait until we do a longer series of PS/transpiration trials under a full range of environmental conditions, and at different times of the year. The degree of soil saturation greatly influences transpiration, and the plants in this study had ample water supplies available while under other circumstances plants may experience variable degrees of water-stress (and stress may differ among species) when results would be much lower. Also, these measurements were taken under full sunlight, but portions of plants obviously are shaded to different degrees, which will reduce photosynthesis, and thus, transpiration. The shade produced by *Arundo* may, in fact, be greater than that created by the other species which would further influence transpiration estimates. Plant density can further influence the local microenvironment, particularly by creating locally high humidity conditions which would also lead to over-estimates of water use by testing leaf surface transpiration in the open away from the plant under canopy, although the equipment can partially compensate for such humidity effects.

Also, we need to develop more accurate leaf area assessments, which will require much more extensive harvesting and measuring of plant parts. The stomatal surface area should be accurately described as well, because some plants have greater stomatal density on the same leaf surface area (even on one side vs. both sides of the leaf), which should be understood in accurately assessing water use. Some stems have photosynthetic tissue, which should be included in transpiration estimates.

In future studies we will determine how PS differs based on leaf types (new vs. old, sun vs. shade leaves) and at different positions in the plant. In particular, we intend to measure how shading affects leaf metabolic activity, but some very preliminary tests indicated that *Arundo* has higher PS activity in the shade than does *Salix*, which would certainly tend to increase the relative difference in water use by the two. That, in combination with estimates under low water availability levels, I think will certainly show that *Arundo* is very significantly and substantively worse than any of the other plant types, in terms of water loss from regional rivers and groundwater.

Literature cited

Coffman, G..2007. Factors Influencing Invasion of Giant Reed (*Arundo donax*) in Riparian Ecosystems of Mediterranean-type Climate Regions. Doctoral dissertation, U.C. Los Angeles.

Hendricks, D.A., S. McGaugh, T. Dudley, K. Lyons. *Arundo donax* (Carrizo Grande / Giant Cane) in Cuatro Ciénegas. http://www.desertfishes.org/cuatroc/organisms/non-native/*Arundo*/*Arundo*.html#Literature

Shafroth, P.B., Cleverly, J.R., Dudley, T.L., Taylor, J.P., Van Riper, C., III, Weeks, E.P. & Stuart, J.N. (2005) Control of Tamarix in the Western United States: Implications for Water Salvage, Wildlife Use, and Riparian Restoration. Environmental Management, 35, 231-246.

Watts, D.A. G.W. Moore & K. Zhaurova. 2008. Ecohydrology and ecophysiology of *Arundo donax* (giant reed) in response to herbivory and drought. Entomol. Soc. America, 93rd annual meeting, Milwaukee, WI.

Zimmerman, P. (1999) Rates of transpiration by a native willow, *Salix exigua*, and by a non-native invasive, *Arundo donax*, in a riparian corridor of northern California. IN:Proceedings of the California Exotic Pest Plant Council. California Exotic Pest Plant Council, Sacramento, California